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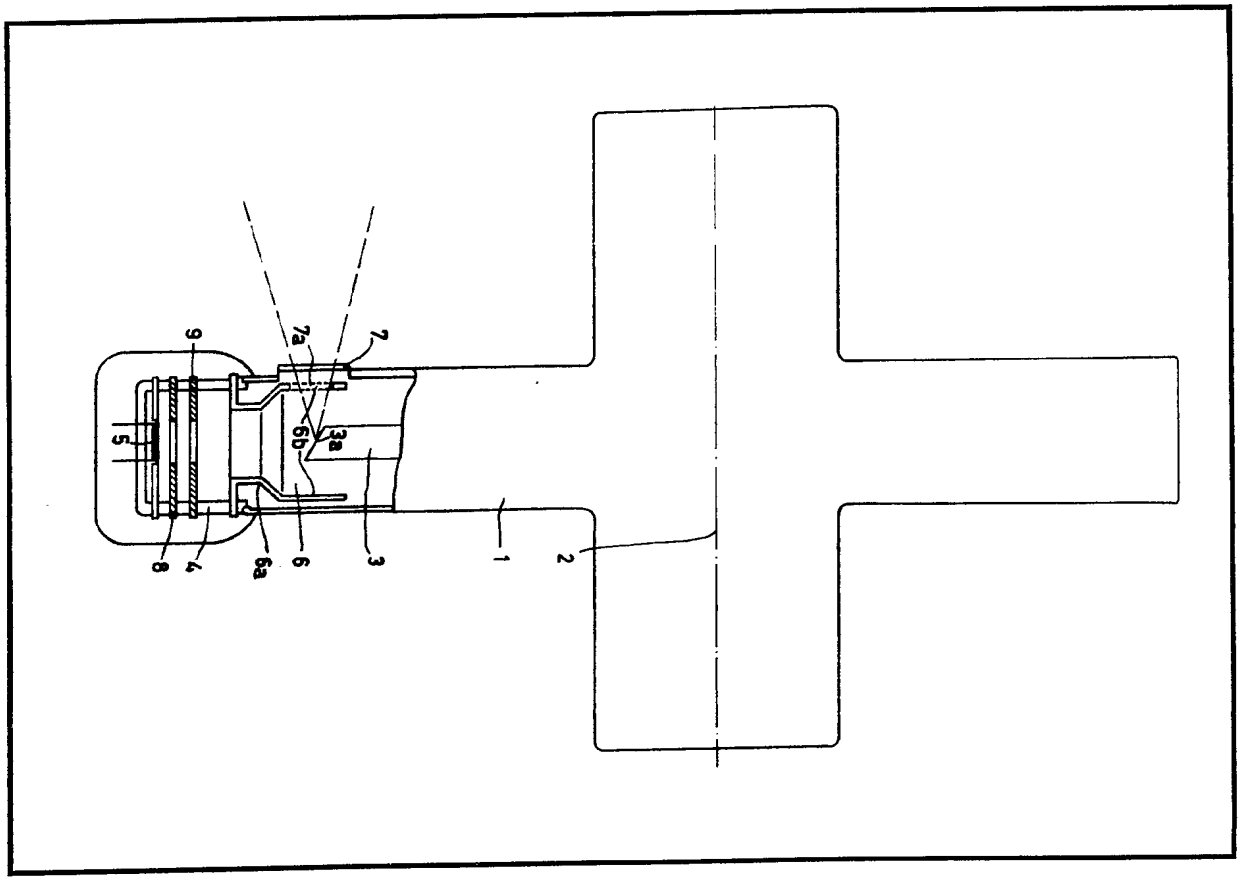
(54) X-ray tubes

(57) In order to reduce stray radiation from an X-ray tube, a first additional electrode (6) is disposed near the anode focal spot (3*a*) on rotating anode 3 and is supplied with a voltage 3–10 kV higher than that of the cathode (5) so as to capture the majority of electrons reflected and generated by secondary emission at the focal spot (3*a*).

A second additional electrode (8), to which a voltage positive with respect to the cathode (5) is applied, may be disposed between the cathode (5) and the first additional electrode (6) to increase the electric field strength in the region of the cathode heater and thereby compensate for space-charge effects due to the first additional electrode 6). Aperture (7a) may be dispensed with for low At. No. materials, and may produce a pre-filtering. The tube current may be switched by grid 9 or grid 8.



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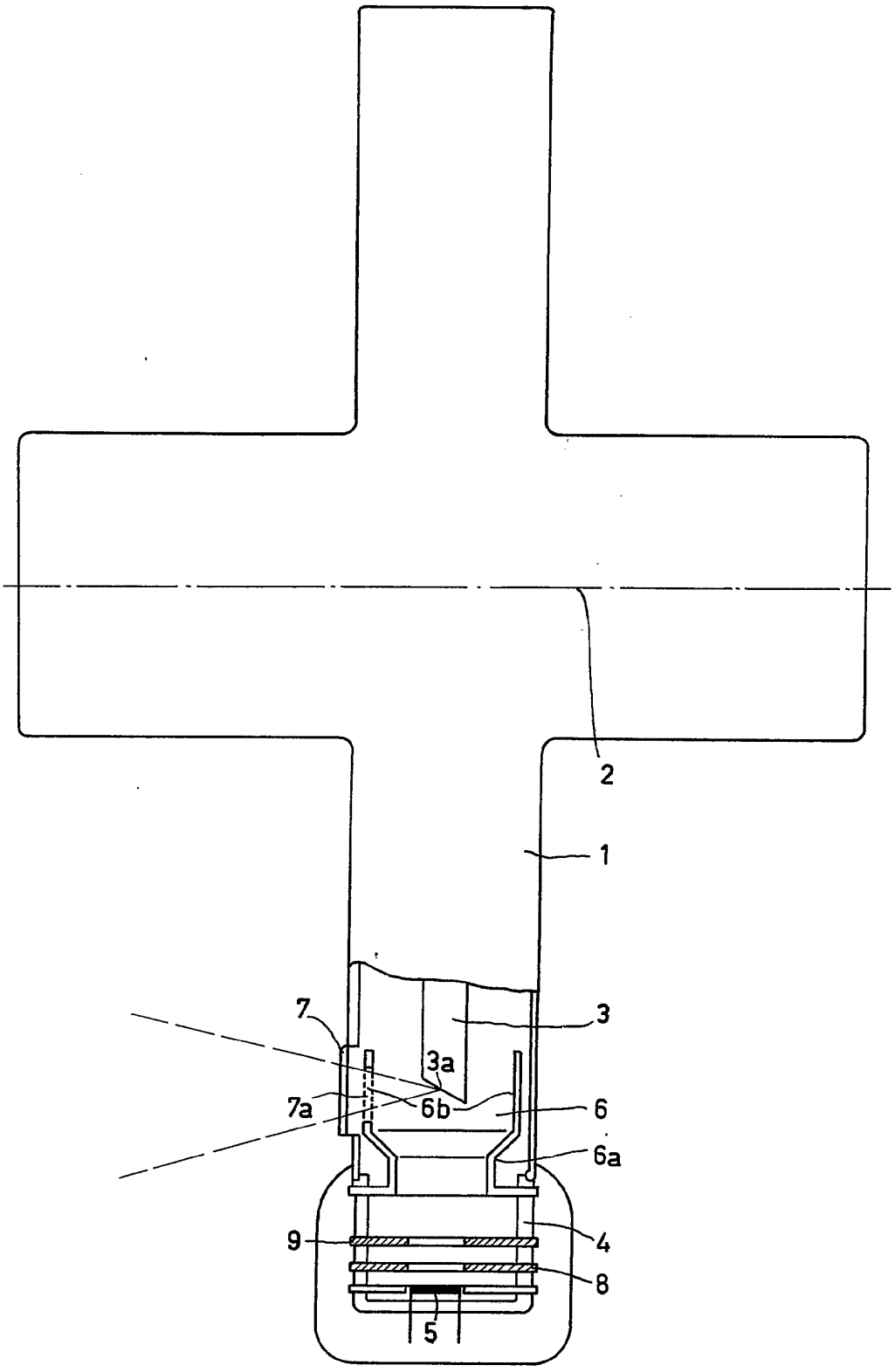
2
1
7
3
3a
7a
6b
6
6a
9
4
8
5

SPECIFICATION

X-ray tube

The invention relates to an X-ray tube comprising a cathode and an anode both mounted in an envelope having an output window for the X-radiation. Such an X-ray tube is disclosed in German Patent Application 2619008, which has been laid open to public inspection.

Stray radiation from an X-ray tube can cause a diffused blackening of an X-ray film during exposure, which has a disadvantageous effect on the picture quality. To suppress such undesired radiation, an X-ray tube as disclosed in the above-mentioned German Patent Application 2619008 is provided with additional diaphragms arranged as close as possible to the focal spot. Such diaphragms pass predominantly only the X-radiation produced in the focal spot. This offers only a limited solution to the problem, and does not prevent the generation in the tube of stray radiation, particularly extra-focal radiation (a term explained hereinafter). The extra-focal radiation emitted from the tube is locally attenuated, the useful radiation emitted from the focal spot not being affected.

It is an object of the invention to provide an X-ray tube wherein the generation of stray radiation, particularly extra-focal radiation, is reduced by internal means.

According to the invention, an X-ray tube of the type mentioned in the opening paragraph is characterized in that the tube further comprises an X-ray tube comprising a cathode and an anode both mounted in an envelope having an output window for the X-radiation, characterized in that the tube further comprises, near an anode focal spot formed in operation on the anode by electrons emitted from the cathode, a first additional electrode adapted to capture a predominant proportion of electrons reflected and produced by secondary emission at the anode focal spot with a voltage which is only somewhat higher than the cathode voltage applied to the additional electrode.

The use in an X-ray tube of electrodes (other than the cathode and anode) has been known for a long time. For example, United States Patent Specification 3,119,931 discloses a grid electrode to which a negative voltage with respect to the cathode can be applied and which is used to rapidly turn-on and turn-off the X-radiation. Furthermore, electrodes having a positive voltage with respect to the cathode have already been used, for example as components of an electro-static lens (United States Patent Specification 2,842,694) or to improve the emission (United States Patent Specification 3,916,202).

In each of these cases, the electrode has a function other than that of the invention, and does not substantially affect the extra-focal radiation.

An example of considerations lying behind the invention is as follows. A proportion of the electrons emitted from the cathode are reflected by the anode at the focal spot substantially without loss, or with only little loss, of energy. The energy of these electrons is insufficient for them to impinge on the envelope of the X-ray tube when this envelope is of metal and has the same potential as the cathode. A large proportion of these electrons therefore return to the anode, as a rule outside the focal spot, and thus produce extra-focal radiation. In an X-ray tube embodying the invention, these electrons are captured by the first additional electrode. To ensure that these electrons will be captured by the electrode, the electrode must have a positive voltage with respect to the cathode, it being a condition that the difference in potential between the electrode and the cathode must be such that the energy of the predominant proportion of the reflected electrons is sufficient for them to impinge on the electrode. It has been found in practice that it is sufficient for the electrode to have a voltage which is approximately 3 to 10 kV more positive than the cathode.

With this relatively small potential difference, the electrons which impinge on this electrode have lost almost all their energy, and thus there is little or no heating of this electrode.

The distance from the electrode to the anode is preferably the smallest possible distance feasible having regard to the voltage between the electrode and the anode. A suitable shape for the electrode depends on the shape of the anode. If, for example, the anode is a fixed anode of cylindrical shape, the electrode is preferably in the shape of a cylindrical cup which surrounds the anode and in the bottom of which, facing the cathode, is an aperture for the "primary" electron beam. In a rotary-anode X-ray tube in which the axis of rotation of the anode is parallel to the primary electron beam and in which the focal spot path is bevelled in known manner (as in the German Auslegeschrift 2455974), it is advantageous to use an electrode the surface of which is parallel to the focal spot path and which has in this region an aperture for the "primary" electrons, the edge of the electrode being folded over.

In an X-ray tube having a metal envelope and embodying the invention, the voltages between the anode and the envelope and between the cathode and the envelope may each amount to half the anode-cathode voltage. If the additional electrode is absent from these X-ray tubes, the predominant proportion of the primary electrons reflected and secondary electrons released at the focal spot indeed

reaches the envelope, but their energy is then still relatively high, so that on the one hand a not inconsiderable proportion is reflected again and/or generates new secondary electrons which impinge on the anode, and on the other hand the envelope is heated to a relatively high degree which may produce excessive heating of the window and the solder joints, particularly when a beryllium window has been provided in the region of the emerging radiation.

In adverse circumstances, it may happen that in the cathode region of a tube embodying the invention, the voltage distribution between anode and cathode is so changed by the first additional electrode or the influence of the anode is so reduced that the anode current is attenuated by space-charge effects. This can be alleviated by arranging a further electrode, to which has a positive voltage with respect to the cathode is applied, between the first additional electrode and the cathode so that the electric field strength in the cathode heater region is increased.

Such an electrode is known *per se* from United States Patent Specification 3,916,202, where it also optionally used, after a corresponding negative voltage has been applied, for turning the tube current on and off.

An embodiment of the invention will now be described, by way of example, with reference to the accompanying diagrammatic drawing, the sole Figure of which shows a rotary-anode X-ray tube, the envelope of which is partly cut away.

Referring to the drawing, reference numeral 1 denotes a metal envelope wherein an anode disc 3 is rotatable about an axis of rotation 2 located in the plane of the drawing. The anode disc 3 has the shape of a truncated cone, on the inclined surface of which an electron beam directed perpendicular to the axis of rotation impinges to form a focal spot 3*a* (as known from United States Patent Specification 3,646,380). For simplicity, the supply of a high voltage to the anode disc, a stator for driving the rotor connected to the anode disc 3, etc. are not shown; they can be formed and arranged in a conventional manner. The envelope 1 is rotationally-symmetrical about the axis of rotation 2, except where a cup-shaped insulator 4, which supports *inter alia* a cathode 5, is connected at one region to the wall of the envelope. During operation, the cathode 5 and also the envelope 1 are at earth potential, and the anode disc has a high positive voltage relative to the metal envelope. The air gap (not shown) between the walls of the envelope and the rotor, which often is relatively wide in such X-ray tubes, can be reduced in known manner, (see for example British Patent Specification 1,527,239) by providing an insulator between the anode disc 3 and the rotor, and by earthing the rotor.

The insulator 4 supports a first additional electrode 6 comprising a funnel-shaped portion 6*a* connected to the insulator 4, this portion 6*a* joining onto two electrode plates 6*b* which extend approximatly parallel to the radial surfaces of the anode disc 3. The electrode 6 is connectable in known manner to a voltage of, for example, 3 to 10 kV which is positive with respect to earth (and therefore also with respect to the envelope), so that the majority of electrons which are reflected and emitted as secondary electrons can travel against the direction of the cathode-anode potential gradient. The electrode 6 and particularly the electrode plates 6*b* surround the anode as close as is possible in view of the high voltage between the electrode and the anode during operation. In order that the radiation generated at the focal spot 3*a* and emitted through a radiation output window 7 should be reduced as little as possible, a window aperture can be provided in one electrode plate in the region where the radiation emerges, as indicated by means of dashed lines 7*a*. However, such an aperture can be dispensed with if the electrode consists of a material having a low atomic number and whose wall thickness, at least *in situ* of the window, is thin enough. With a suitable thickness, a pre-filtering of the radiation by means of the electrode wall, which is still required in X-ray tubes for X-ray diagnosis, can be effected there.

In order to direct the paths of, if possible, substantially all the reflected and secondary electrons to the electrode 6, the aperture at the narrow end of the funnel 6*a* should be as small as possible. However, this strongly reduces the influence of the anode near the cathode so that, especially with low voltages, the anode current can be limited by space-charge effects. This can be counteracted by providing near to the cathode a further electrode 8 which is also supported by the insulator 4 and which has a positive voltage with respect to the cathode. This electrode may be a grid electrode but it is alternatively possible to use an electrode as described in United States Patent Specification 3,916,202. Such an electrode increases the field strength in the cathode region and also increases the emission current for low values of the tube voltage (i.e. anode-cathode potential difference).

Furthermore, there can be arranged between the electrode 6 and the electrode 8 an additional control grid 9 which can be used to switch the tube current and consequently, the X-radiation on an off by the application of a suitable bias voltage. However, it is also possible to use the grid 8 for this purpose in the manner known from United States Patent Specification 3,916,202, a positive voltage being applied to this electrode during a photographic recording or X-ray examination and a negative voltage being applied to it at the end

thereof.

The cathode-anode voltage in an X-ray tube such as that described above with reference to the drawing may typically be about 50 kV.

CLAIMS

1. An X-ray tube comprising a cathode and an anode both mounted in an envelope having an output window for the X-radiation, characterized in that the tube further comprises, near an anode focal spot formed in operation on the anode by electrons emitted from the cathode, a first additional electrode adapted to capture a predominant proportion of electrons reflected and produced by secondary emission at the anode focal spot with a voltage which is only somewhat higher than the cathode voltage applied to the additional electrode.

2. An X-ray tube as claimed in Claim 1, characterized in that the tube is adapted to operate with a voltage which is substantially in the range of 3–10 kV higher than the cathode voltage applied to the additional electrode.

3. An X-ray tube as claimed in either of the preceding Claims, characterized in that a second additional electrode is arranged between the first additional electrode and the cathode so that the electric field strength is increased thereby in the region of the cathode heater with a voltage positive with respect to the cathode applied to the second additional electrode.

4. An X-ray tube as claimed in Claim 3, characterized in that a control grid is arranged between the first and second additional electrodes.

5. An X-ray tube substantially as herein described with reference to the accompanying drawing.

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